I. Introduction

A. The Aeronomy Laboratory: Our Aims, Approach, and Organization

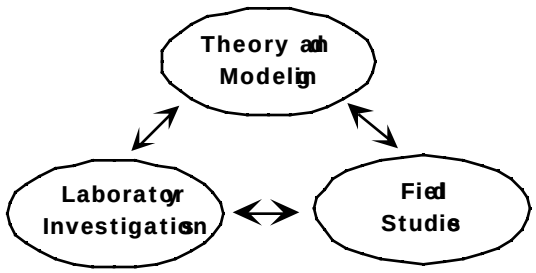
aer•on•o•my (a(e)r-an´-o-me) **n**. [fr. Gk aero-]
a branch of science that deals with the atmosphere of the earth and the other planet with reference to their chemical composition, physical properties, relative motion, and responses to radiation from space.

Our aim: Understanding atmospheric processes to improve environmental prediction. The Aeronomy Laboratory carries out fundamental research on the chemical, dynamical, and radiative processes of the Earth's atmosphere to improve the capability to observe, understand, and predict its behavior. In addition to helping improve the fundamental understanding of the atmosphere, the Aeronomy Laboratory also assists our scientific community in their periodic taking stock of the current state of understanding and in their description of this understanding in "user-friendly" terms to those who use this scientific information. Sections II – IV of this summary describe, in more detail, the Laboratory's research – its rationale, approach, accomplishments, payoffs, and plans – all in the context of the environmental issues of today.

The research approaches used: Integrated laboratory, field, and theoretical studies. The Laboratory's research involves:

- investigations under controlled conditions in the laboratory,
- field measurements in a variety of environments (both in a campaign mode and via regular observations), and
- regional and global theoretical modeling.

A hallmark of the Laboratory is the integration of these three endeavors to build a better predictive understanding. Laboratory investigations characterize fundamental properties of chemical reactions, which are needed by predictive models and are also a test bed for the development of new analytical techniques. Field campaigns provide the observations to test the predictive capabilities of models, as well as indicate the potential of heretofore unknown processes that should be examined in the laboratory. Theoretical models, via sensitivity studies, evaluate the impact of processes on the global picture, probe which of a basket of poorly characterized chemical processes would have the biggest payoff for laboratory investigations, as well as help guide the design of regional or global field campaigns. This booklet will point to numerous examples of these synergistic interactions.



Providing scientific input for the decisions of governments, industry, and the public regarding current environmental issues. The chemical, dynamical, and radiative processes of the atmosphere are the gears, belts, and pulleys of atmospheric change. As such, their identification and characterization are a fundamental necessity for understanding and predicting the behavior of regional and global phenomena. The Aeronomy Laboratory focuses on understanding the

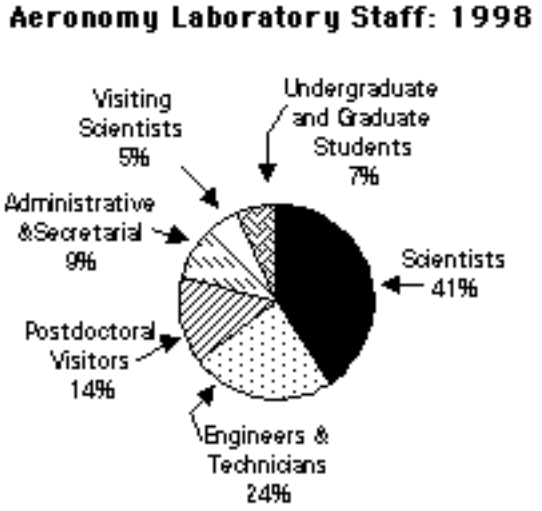
- stratospheric ozone layer,
- regional and global tropospheric chemistry, and
- the climate system.

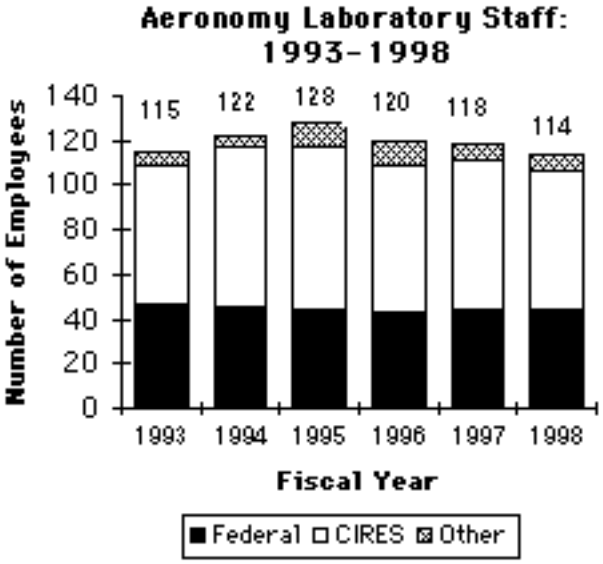
Several societal environmental issues are embraced within these three phenomena: depletion of the polar and global ozone layer, increases in regional surface-level ozone pollution, enhancement of fine particles in many continental areas, changes in the acidity of rainfall in Eastern North America, the waxing and waning of short-term climate changes influenced by the El Niño – Southern Oscillation (ENSO), and the potential of longer-term climate changes from the

growing abundance of radiatively important trace gases and particulate matter. A key to informed decisions regarding these challenging environmental issues is sound scientific understanding of the phenomena involved. As this booklet aims to show, the Aeronomy Laboratory's commitment is to providing that scientific input in an effective form to those who need it.

How we have organized ourselves: Interactive groups. The Aeronomy Laboratory has seven Program Areas and a Directorate. The Program Areas are the research focal points within the Laboratory. The groups vary in size from seven to twenty four. Many of groups often have subgroup foci (e.g., associated with a complex airborne field instrument). The Aeronomy Laboratory Staff are listed by Program Area in Appendix A. Generally, each Program Area has a focus on one or two particular components of the Laboratory's research (e.g., stratospheric chemistry and dynamics), and generally each Program Area has a common research approach (e.g., field measurements). However, as noted above, much of the Aeronomy Laboratory's research is conducted with the collaborative involvement of more than one Program Area.

B. The Aeronomy Laboratory Staff: The Fundamental Resource





Who we are: A broad spectrum. The Aeronomy Laboratory currently consists of 114 scientists, engineers, technicians, administrative support personnel, secretaries, and graduate and undergraduate students. *Their professional interests, expertise, efforts, accomplishments, and plans are what the Aeronomy Laboratory is, does, and will be.* The professional titles and roles of our staff are given in Appendix A.

Visitors vis-a'-vis permanent staff: A highly productive ratio. The permanent staff of the Aeronomy Laboratory is about 75% of the total. The remaining percentage represents visiting scientists, postdoctoral researchers, and graduate and undergraduate students. These percentages have remained roughly the same over the past several years. Aeronomy Laboratory research has been enriched greatly over the years by the relatively large number of visitors and students. Not only do they bring new ideas, approaches, and perspectives, but also, upon reaching their subsequent institutions, they are the node for new collaborations between that institution and the Aeronomy Laboratory.

Staff size: A maximum in FY 1995; the current size now comparable to that of FY 1993. During the early 1990s, the size of the staff of the Aeronomy Laboratory increased about 10%. However, with the reduction of support that occurred in FY 1996, we reduced staff in the years that followed. The current number of staff of the Aeronomy Laboratory is comparable to that of 1993. Stability is our

aim, since it fosters the longer-term commitments required to constructively address the research that we do (e.g., the sequence of new analytical development, field testing and application, and resulting new theoretical simulations or predictions). This goal is obviously related to our approach toward financial support, which is described below.

Departures and arrivals: Our "average age" remains about 40. Special notice continues to be given to the overall "graying" of many institutions, i.e., evidence for a steady increase of the average age of the staff of the institution. It is a particularly noteworthy index for research institutions, since it is one measure of the influx of new personnel, hence ideas and perspectives. The Aeronomy Laboratory is bucking such trends, the mean age being between 39 and 42 over the past six years. Special attention has been given to looking ahead to the Aeronomy Laboratory of the next decade, and most of our new hires have focused on recruiting the young scientists that will lead and carry out the research of that Laboratory.

C. Our Institutions: Of Whom Are We a Part?

NOAA/CIRES: A vital and unique partnership. The NOAA Environmental Research Laboratories (ERL) has nine Joint Institutes with various universities. In Boulder, the Cooperative Institute for Research in Environmental Sciences is a joint endeavor of the University of Colorado and the Environmental Research Laboratories, having been founded in 1967. Over these 30 years, it has played a vital role in the local Federal - State venture involving the University and the seven ERL organizations and other NOAA entities in Boulder. Currently, the CIRES staff associated with the Aeronomy Laboratory is 54% of the personnel cited above and listed in Appendix A. The CIRES component reflects a spectrum of professional levels, ranging from senior researchers to students and is involved with the research of all of the Aeronomy Laboratory's Program Areas. CIRES has a professional career track system, and the classifications and rank of the CIRES staff associated with the Aeronomy Laboratory are identified in Appendix A.

A Federal-University Partnership

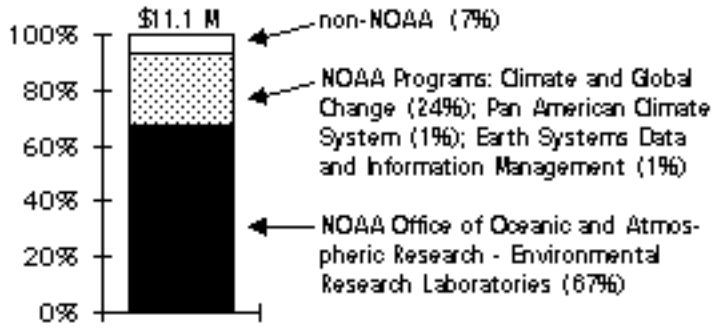
NOAA's environmental laboratories: Who are our siblings? The Aeronomy Laboratory is one of twelve Laboratories and Centers of the Environmental Research Laboratories (ERL). These organizations of ERL are located in seven states, from the East Coast to the West Coast. Within the broad aim of improving the understanding and prediction of geophysical phenomena that relate to the well-being of humankind, the research emphases of the individual organizations are focused on particular aspects of the Earth system (e.g., from solar influences to deep-ocean circulation), on varying time and spatial scales (e.g., from severe storms to global climate trends), and on using different research approaches (e.g., from technology to general circulation model development). The Aeronomy Laboratory interacts with several other ERL Laboratories and has joint publications with four. The collaborative research endeavors are identified in Sections II – IV below.

Across NOAA: Where do we fit in? The Environmental Research Laboratories are the in-house part of NOAA's Office of Oceanic and Atmospheric Research (OAR), which is the research component of NOAA and is one of NOAA's five "Line Offices". The other four Line Offices focus on providing NOAA's weather, satellite/data, ocean, and fishery services. The Aeronomy Laboratory also interacts strongly with the NOAA-wide Programs, most notably the Climate and Global Change Program. Lastly, NOAA's overall Strategic Plan has stewardship

(e.g., fish, endangered species, and coasts) and assessment and prediction (e.g., a spectrum of time-scale phenomena) portfolios. The Aeronomy Laboratory helps provide the information needed in and the leadership for the assessment/prediction portfolio.

D. Our Budget: Where It Comes From and Where It Goes

Our funding: The various types. The funding level of the Aeronomy Laboratory in Fiscal Year 1998 is $11.1M. These funds come from different sources. The origin and nature of each is important to the Laboratory and the conduct of its research and hence are described briefly here.



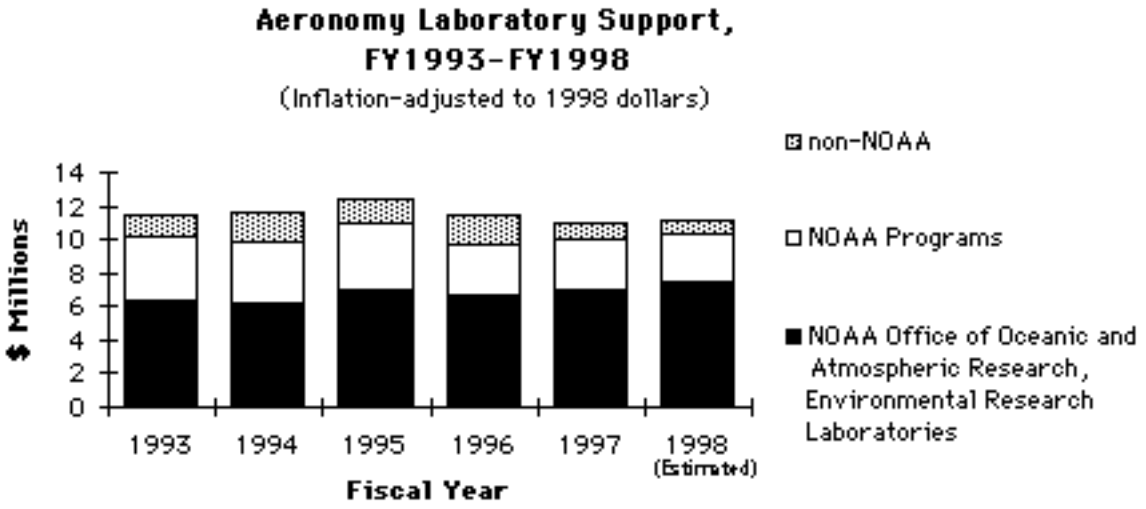
Aeronomy Laboratory FY 1998 Funding Sources

- *OAR/ERL funds.* This $7.5M support comes through our Line Office, OAR, and thence ERL. They include augmentations via new OAR/ERL research initiatives that have been successfully sought upward through NOAA and allocated by the Congress (acid deposition in 1982/84, radiatively important trace species in 1986/87, and regional tropospheric chemistry in 1994/8).

- *NOAA-wide programs.* The Aeronomy Laboratory's participation in and contribution to the NOAA-wide Climate and Global Change Program is supported by $2.7M via the Atmospheric Chemistry Project and the Climate Observations Project. The NOAA-wide Pan American Climate System (PACS) and the Earth Systems Data and Information Management (ESDIM) Programs provide additional support ($185K).

- *Elsewhere.* A variety of non-NOAA sources make up the remaining $0.7M of our FY 1998 funding (e.g., NASA, DOE, and the private sector). By choice, the other-Agency funds have been a relatively small component of the Aeronomy Laboratory support, typically being 10% over the past several years. These funds have generally been directed toward assistance with instrument development associated with collaborative field campaigns (e.g., stratospheric ozone layer) or installations (e.g., radars).

Trends: Ups and downs – but manageable. Because of the variety of sources and the vicissitudes of Federal budgets, the total fiscal support for the Aeronomy Laboratory varies from year to year (see figure on next page). FY 1995 was a maximum in the budget of the Aeronomy Laboratory. Taking the longer-term view (i.e., the past decade), the changes have been manageable. But, this is no accident. Our participation in the NOAA Climate and Global Change Program beginning in the late 1980s and our starting the OAR/ERL research initiative in regional tropospheric chemistry (the "Health of the Atmosphere" program) in the mid-1990s both have kept the Aeronomy Laboratory total budget from declining over the longer term due to inflation, cost-of-living, and other "hits".

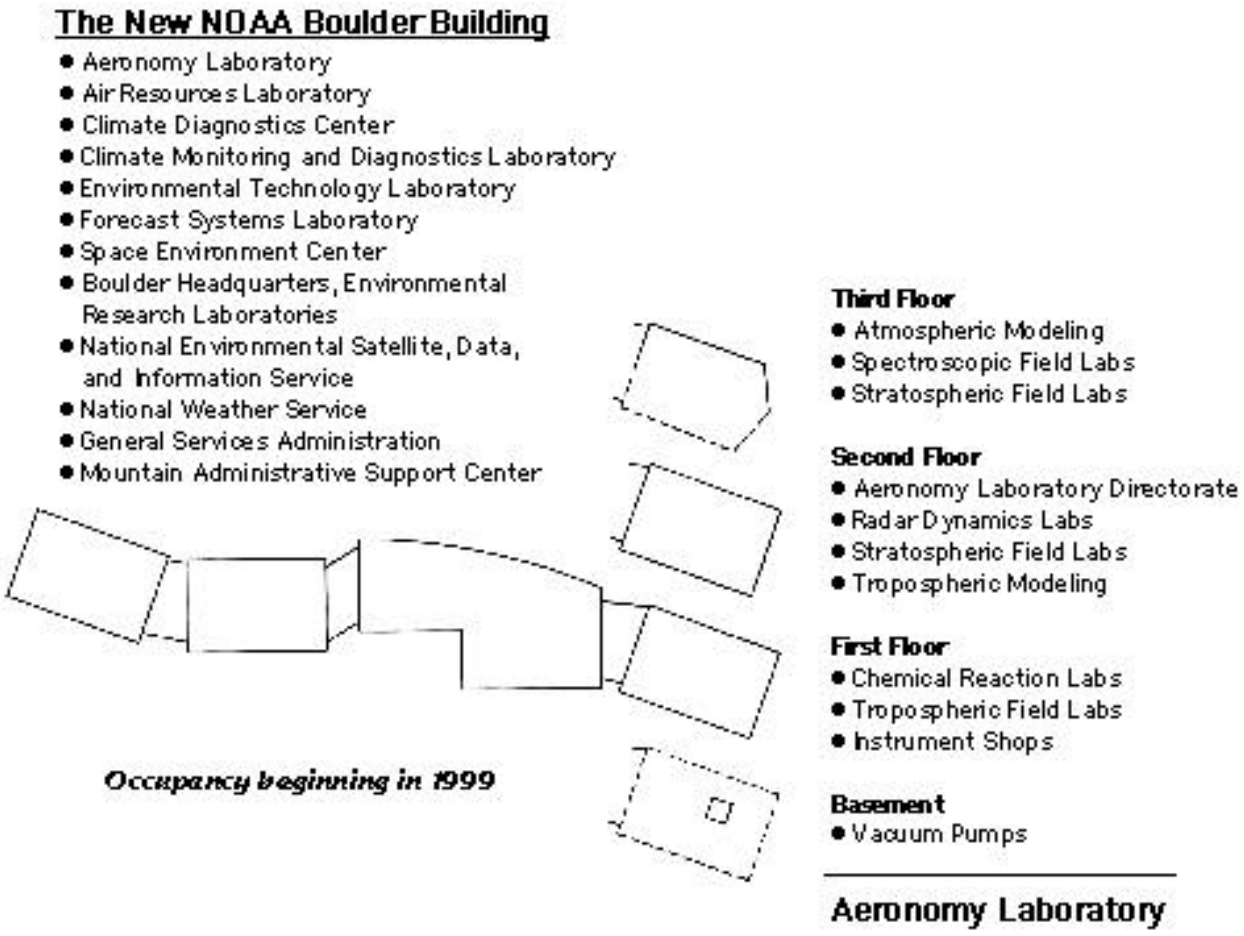


Expenses: Where it goes. The largest component of the Aeronomy Laboratory annual expenses is salaries and the associated overhead. For the Federal and CIRES staff, this amounts to 75% of the budget in the current fiscal year. This fraction has increased somewhat over the past decade. But, an important Aeronomy Laboratory aim is that salaries can be met by NOAA support, and that aim continues to be achieved. The non-salary component of the Aeronomy Laboratory budget goes to parts and supplies, instrument shop time and other services, travel, shipping, capital equipment, and utilities, all reflecting the types of research that we do.

E. Our Facilities: At Home and Away

Home: Boulder, Colorado. All Groups of the Aeronomy Laboratory are located at the Broadway Campus of the Department of Commerce Laboratories (housing the National Institute of Standards and Technology – NIST, some NOAA organizations, and the National Telecommunications and Information Administration – NTIA). In addition, the Aeronomy Laboratory operates facilities outside of Boulder: (i) Fritz Peak Observatory, west of Boulder (remote-sensing atmospheric observations); (ii) the Flatland Radar in Illinois (atmospheric dynamics); and (iii) the Trans-Pacific Profiler Network in the Western Equatorial Pacific (El Niño - Southern Oscillation meteorology). The record of observations at the sites aims to elucidate the processes involved in episodic and periodic phenomena and trends over the longer term.

The new building for all of NOAA in Boulder. Over the past thirty years, the Aeronomy Laboratory has been housed in three separate buildings on the Broadway site. In recent years, this has included temporary trailers. Therefore, it is with high anticipation that we look forward to moving into the Aeronomy Laboratory quarters within the nearly completed new NOAA Boulder building (as shown on this report's cover). Over ten years in the planning, proposal, approval, and construction stages, this building will constitute a quantum-level improvement in our carrying out our research aims: (i) all of our groups will be collocated for the first time, which



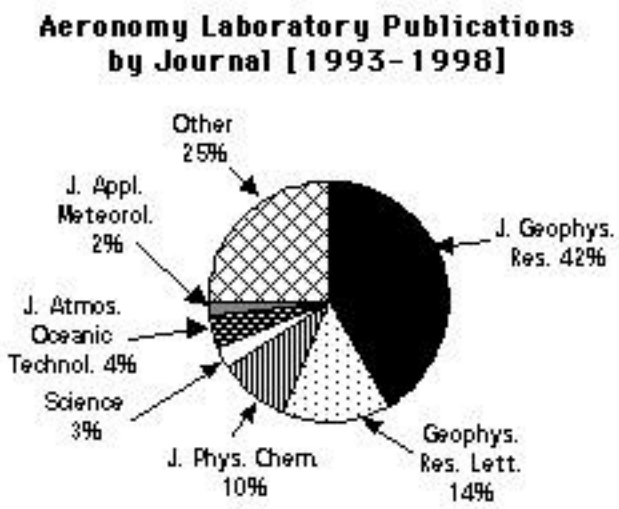
will substantially enhance the effectiveness of interactions; (ii) adequate laboratory space will exist for the first time, along with modern facilities for such activities; and (iii) the proximity to other ERL and NOAA organizations will foster new scientific collaborations.

F. Our Colleagues: Interactions in the Scientific Community

A basic indicator: Collaborative publications. In addition to the interactions among the internal groups of the Aeronomy Laboratory noted above, an additional hallmark of the Laboratory's research through the years has been strong and extensive collaborative activities with other national and international research institutions, e.g., universities, other Federal Agencies, other ERL Laboratories, and the private sector. One of the most telling indications of these close scientific interactions are the publications listed in Appendix B; *the majority of them involve coauthors from other institutions.* In addition to these basic scientist/scientist collaborations, the Aeronomy Laboratory has been involved in many jointly planned and conducted field campaigns, in which inter-organizational breadth was one of the key factors in the capability to carry out the campaign. Many collaborations will be noted in Sections II – IV below. In such field campaigns, The Aeronomy Laboratory not only had its researchers involved, but also our staff assisted with the logistics, engineering, communications, and computing.

G. Our "Products" and Our "Customers": The Bottom Line

Where we publish. Our basic "product" is scientific information that elucidates atmospheric processes needed for an improved predictive understanding of the chemical/radiative/dynamical behavior of the atmosphere. One of the key tangible records of the "products" of the Aeronomy Laboratory research are the scientific papers of the staff. The emphasis focuses almost exclusively on the peer-reviewed journals. As illustrated here and demonstrated by the list of 1993 - 1998 peer-reviewed scientific publications in Appendix B, these include the leading letter-style, full-article research journals, and invited book chapters in the atmospheric sciences. It is indicative of the Laboratory's research approach that these journals include those that focus on (i) experimental and theoretical descriptions of atmospheric phenomena, (ii) characterizations of fundamental photochemical processes, and (iii) descriptions of advances in atmospheric measurement methodologies. In association with these publications are contributions to Web-based data sets and other data archives.



Our information "customers". In addition to our direct collaborators noted above, the results of Aeronomy Laboratory research are input information to the goals, services, missions, etc. of a wide spectrum of institutions or organizations. A few examples of each given here. Others are noted in Sections II – IV that follow.

- *Other ERL Laboratories.* There are many complementary facets within the set of ERL Laboratories. As a consequence, the research results of one Laboratory are information that helps another Laboratory meet its mission. Examples include: (i) the insight that the Aeronomy Laboratory's chemical process understanding brings to the trace-gas monitoring records of the Climate Diagnostics and Monitoring Laboratory (CMDL) and vice versa; (ii) the synergy of the chemical/spectrographic measurements of the Aeronomy Laboratory and the suite of meteorological measurement methods of the Environmental Technology Laboratory (ETL) and the radiation monitoring of CMDL; (iii) the complementary nature of the atmospheric chemistry focus of the Aeronomy Laboratory and the general circulation modeling focus of the Geophysical Fluid Dynamics Laboratory (GFDL), and (iv) the utilization of the Aeronomy Laboratory's tropical Pacific wind-profiler observations in the climatic analyses carried out by the Climate Diagnostics Center (CDC) and vice versa.

- *Within NOAA.* The Aeronomy Laboratory's understanding of chemical processes is input the understanding of the behavior of stratospheric ozone trends of the National Environmental Satellite, Data, and Information Service (NESDIS) and similarly for the temperature trends of the National Weather Service (NWS). Further, Aeronomy Laboratory research results that elucidate global phenomena are part of the information portfolio of the Climate and Global Change Program of NOAA's Office of Global Programs and Aeronomy Laboratory staff help with the Program's management.

- *Governments.* In addition to helping strengthen the science, the Laboratory has also focused on assisting with periodic assessments of the state of the science, which is part of NOAA's role as an environmental information service. Not only do such scientific reviews help guide research directions of the scientific community, but they also serve as scientific input to those required to make policy decisions with regard to environmental issues and the public welfare. Appendix C provides additional details about the Aeronomy Laboratory contributions to such state-of-understanding assessments. Aeronomy Laboratory staff have helped and are continuing to help by serving in a variety of roles: assessment cochair and coordinating editor, steering committee members, chapter chair and authors, and scientific contributors and reviewers.

- *Industry.* In addition to the state-of-science assessments noted above, the Aeronomy Laboratory research results are important input to industry. A notable example is the long-standing evaluation of potential substitutes for the now-banned ozone-depleting chemical compounds. Costly "false steps" by industry were avoided by early "heads -up" information about the ozone-friendliness of new candidate compounds.

- *The public: Everyone's ultimate "customer".* The Aeronomy Laboratory has increasingly focused on the challenging task of taking the results of science to the public in user-friendly terms. "The public" is, of course, a very diverse part of the "customer" spectrum, thereby necessitating a rather broadband transmission. Examples of activities in our outreach communication aim are: (i) cochairing the less-technical Executive Summaries that are part of scientific assessments, (ii) pioneering the "Common Questions About Ozone" has become a regular feature of assessments of the science; and (iii) describing the understanding of environmental issues in schools, town meetings, and local clubs.

- *Current outreach activities.* In the "Communicating Our Science" section of each of our quarterly Newsletters, *"On the Air!"*, we highlight for ourselves and others the current Aeronomy Laboratory commitment to outreach by summarizing the staff's activities over those three months that link to the spectrum of our customers. A sample issue is provided in Appendix D.

With this "end-to-end" focus that goes from scientific discovery to facilitating the utilization of environmental information, the Aeronomy Laboratory has sought to contribute to all steps of the process that leads to *science in the service of humankind*.